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Optical Distribution of OFDM and Impulse-Radio UWB in FTTH networks

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Abstract: Proposal, experimental demonstration and performance comparison of impulse-radio UWB and OFDM UWB distribution in FTTH networks for high-definition audio/video broadcasting is presented. OFDM-UWB exhibits better performance compared with its impulse-radio counterpart with better spectral efficiency.

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1. Introduction

Ultra-Wide Band (UWB) technology is receiving a lot of attention, in particular in the US and in Europe due to its unique features: low self-interference, tolerance to multi-path fading; low probability of interception and capability of passing through walls while maintaining the communication [1]. UWB is being introduced in the market for high bitrate high definition (HD) in picocell range replacing HD cabling [2]. This paper proposes the distribution of high bitrate multimedia content in fiber-to-the-home (FTTH) networks employing UWB signals. This approach is depicted in Fig. 1: UWB signals are generated at a central node (Head-End) and are distributed on fiber to a number of subscribers. At the subscriber premises, the UWB-on-fiber signal is photodetected, filtered, amplified (O/E block in Fig.1) and radiated (antenna block in Fig.1) to broadcast HD content to an UWB-enabled TV set or computer. This approach combines UWB advantages with the economy and bandwidth (BW) capacity of FTTH networks. This is advantageous over other distribution networks, like hybrid fiber-coax (HFC), because no trans-modulation of frequency up-conversion stages are required at the subscriber premises, leading to lower deployment cost.

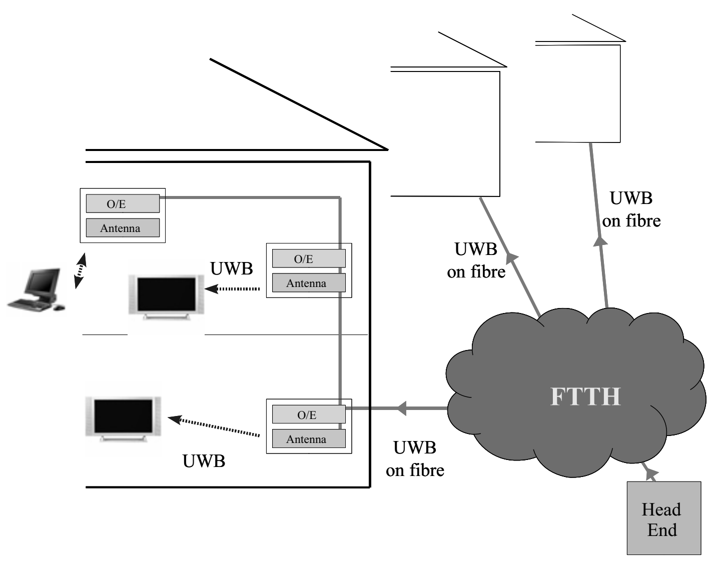

Figure 1. UWB on fibre to distribute high bitrate multimedia concept.

UWB is defined as a radio modulation technique with a minimum bandwidth of 500 MHz or at least 20% greater than the centre frequency of operation. UWB signals are allocated in band between 3.1 to 10.6 GHz with -41.3 dBm/MHz equivalent isotropic radiated power (EIRP) and in the 1.99 to 3.1 GHz with -51 dBm/MHz EIRP, as in FCC part 15 [3]. Two UWB implementations are mainstream: (A) Impulse-Radio UWB (IR-UWB) transmits data by short impulses (monopulses) achieving data rates over 1 Gbit/s @ 10 m [4]. (B) The OFDM-UWB approach divides the spectrum (3.1 to 10.6 GHz) into 14 bands 528-MHz wide. Each band bears 128 carriers PSK modulated achieving 53 Mbit/s @10 m to 480 Mbit/s @3 m [5]. Range extension over 30m including MIMO processing has been recently proposed [6] which would enable UWB distribution of HD video covering a whole home or office.

2. Proof of concept demonstration set-up

Fig. 1 shows the experimental proof-of-concept setup. This setup evaluates 1.25 Gbit/s UWB –adequate for HD video- transmission on different FTTH fibers up to 60km paths from a "Head-End" (Fig.1) to the user premises [7].

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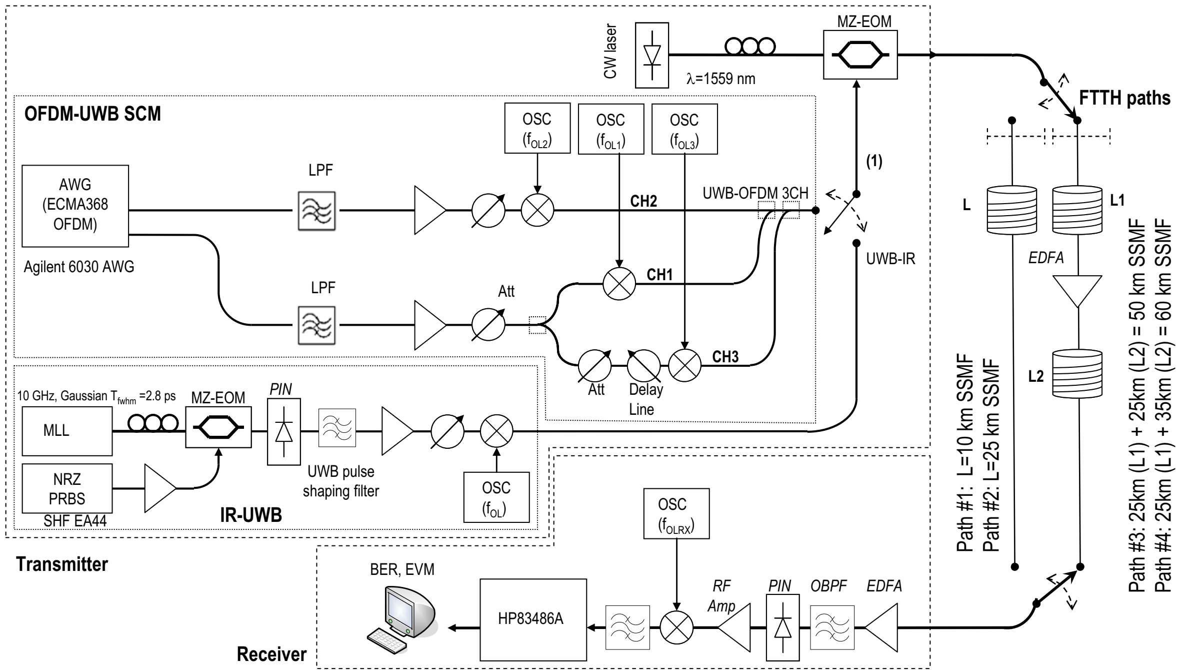

Figure 2. UWB on FTTH demonstration set-up. Both IR-UWB and OFDM-UWB are generated bearing 1.25 Gbit/s bitstreams and are transmitted through SSMF for performance comparison. Four FTTH SSMF paths from 10 km to 60 km are considered in the evaluation.

The set-up shown in Figure 2 compares two UWB implementations: IR-UWB meeting the FCC spectrum mask [3] and OFDM-UWB as in ECMA regulation [8]. Both provide 1.25 Gbit/s capacity, adequate for HD video distribution. The OFDM-UWB section in Fig.2 generates three OFDM channels in sub-carrier multiplex (SCM) with 124 carriers per channel including pilots [8], with QPSK modulation per carrier giving an aggregated bitrate of 1.25 Gbit/s. The central channel (labeled CH2 in Fig.2) -channel under study – is located at f_{OL2}= 2.5 GHz and is surrounded by two adjacent channels centered at frequencies f_{OL1}= 1 GHz and f_{OL3}= 4 GHz respectively in order to include third-order intermodulation effects. The three channels are generated by an AWG6030 arbitrary waveform generator. All channels bear uncorrelated PRBS (2^{10}-1 pattern) data. The IR-UWB section shown in Fig.2 generates an impulse radio UWB meeting the FCC UWB spectral mask in the 3.1~10-6 GHz band. IR-UWB monopulses are based on a 10 GHz 2.8ps T_{fwhm} Gaussian pulse train (mode-locked laser, MLL in Fig. 2). The pulse train is gated by a Mach-Zehnder electro-optical modulator (MZ-EOM) with 1.25 Gbit/s PRBS NRZ data. The gated optical pulses are photodetected, shaped to 283 ps T_{fwhm} monopulses and up-converted to f_{OL}=6.6 GHz for fiber transmission.

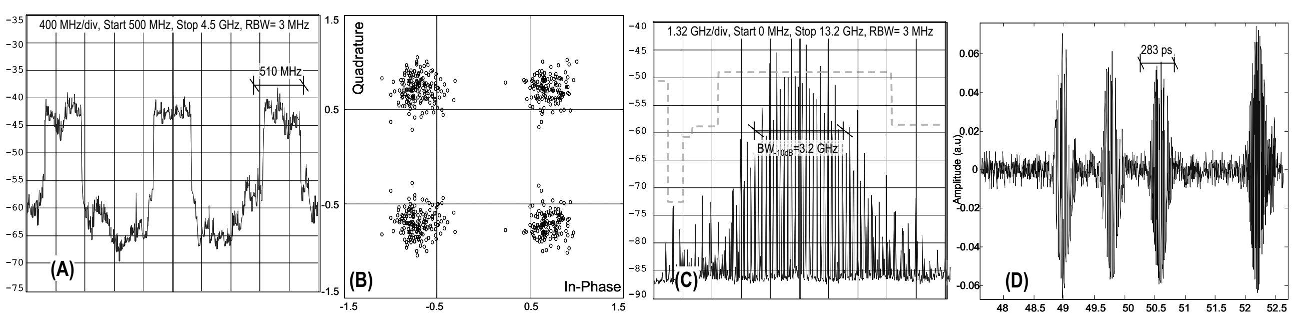

Figure 3. (A) OFDM electrical spectrums at the transmitter. (B) Received OFDM-UWB (QPSK carriers) constellation (528 symbols shown) after pilot compensation. Aggregated bitrate 1.25 Gbit/s. (C) IR-UWB transmitted RF spectrum. (D) Modulated electrical IR-UWB signal.

The two UWB versions are modulated by a 20 GHz MZ-EOM at quadrature-bias (QB) polarization and transmitted through the four FTTH paths shown in Figure 2. After transmission, the signals are detected by a conventional direct detection scheme comprising a 0.8 nm @ 0.5 dB optical filter, a PIN photodiode (0.65 A/W, 50 GHz BW), down-converted to baseband, sampled by an HP83486A module (20 GHz BW), equalized from pilot information (OFDM case), demodulated, and their performance evaluated for different power levels.

4. Experimental results

Two sets of measurements have been done on the four transmission paths: Path #1=10 km, Path#2=25 km, Path#3=50 km and Path#4=60 km. As an example, Fig. 3(A) shows the spectrum of the three OFDM channels in SCM configuration before transmission –point (1) of the set-up of Fig. 2. Fig. 3(B) shows the corresponding received constellation after equalization using the pilot tones in this case. Fig. 3(C) and Fig. 3(D) show the IR-UWB transmitted RF spectrum at point (1) of Fig. 2 and the modulated electrical signal in IR-UWB respectively. It can be seen here that the monopulses occupy the 5~8.2 GHz band (-10dB BW) meeting FCC regulation. The BER achieved by QPSK-OFDM UWB and IR UWB are shown in Figure 4 for all the FTTH paths (10 km – 60 km) considered.

5. Conclusion

The experimental results demonstrate the feasible distribution for 1.25 Gbit/s UWB signals achieving error-free (BER<10^{-9}) operation at 60 km with both IR and OFDM-QPSK UWB versions. Better performance for the OFDM UWB can be observed in Fig.4. The performance penalty observed in IR-UWB is due to the large bandwidth employed (3.2 GHz at -10dB) –required to provide 1.25 Gbit/s bitrate-. IR-UWB performance degradation is caused by the non-perfect operation of up and down-converting mixers over such bandwidth.

It should be noted also that the spectral efficiency achieved is 0.4 (IR-UWB) vs. 0.83 bit/s/Hz (OFDM-QPSK). FTTH reach vs. spectral efficiency is a trade-off that must be considered by operators deploying this technology

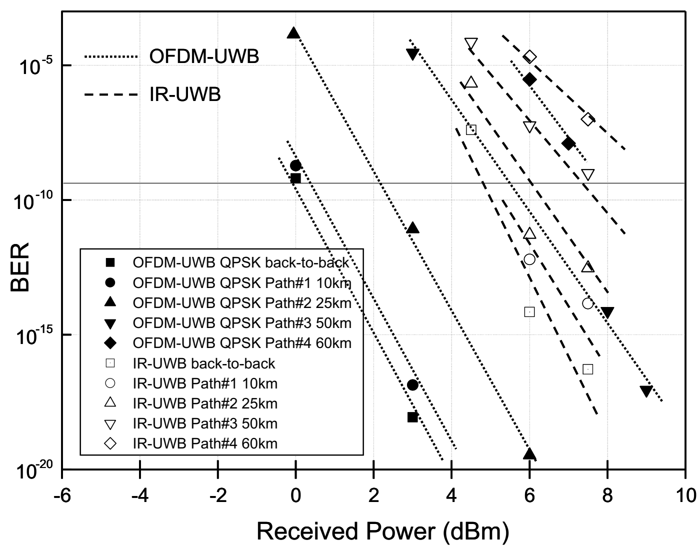

Figure 4. UWB 1.25 Gbit/s for the four FTTH SSMF paths comparison: OFDM-UWB three channels SCM (QPSK per carrier) –dotted lines- vs. IR-UWB –dashed lines-. OFDM achieves error-free operation at lower received power for all FTTH paths.

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